networktest

# Own the Air:

## Testing Aruba Networks' Adaptive Radio Management (ARM) in a High-Density Client Environment

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# Contents

## 1: Executive Summary

RF management is a challenging endeavor, and nowhere more so than in dense WLAN environments. The problems are manifold: Legacy clients take too much air time. Channels get saturated. Noise on one channel spills over into others. Clients get distributed unfairly across bands and channels. These problems all produce the same result: degraded application performance in high-density environments.

Aruba Networks' **Adaptive Radio Management** (ARM) features aim to boost application performance for 802.11n and legacy clients, especially in high-density environments such as offices, conference rooms, and lecture halls. The ARM features, which are included as part of the base ArubaOS available on every Aruba Mobility Controller, introduce new mechanisms for managing air time and dynamically balancing clients across bands. The ARM features require no change on WLAN clients.

Aruba commissioned Network Test to evaluate the efficiency of ARM features. Using a massive (80-client) over-the-air test bed[1], Network Test assessed ARM features both individually and in concert, in the latter case using strict adherence to service-level agreements as one of the key metrics.

The ARM features delivered significant performance improvements in every test case. Among the key findings in this project:

- ✓ In an 80-client test, ARM boosted aggregate goodput by 50 percent, to nearly 600 Mbit/s, compared with test cases without ARM enabled
- ✓ All 80 clients met SLA targets with ARM. In contrast, only 23 percent of clients met SLA targets when engineers disabled ARM
- ✓ ARM's air time fairness feature nearly doubled transfer rates for a client to an access point without significantly reducing rates for a distant client on the same network
- ✓ Air time fairness delivered fourfold improvements in transfer rates for 802.11n clients contending for bandwidth with legacy clients, while simultaneously reducing channel utilization
- ✓ The noise-aware ARM feature moved clients away from channels beset by outside interference
- ✓ ARM's band steering feature dynamically moved clients away from the crowded 2.4-GHz spectrum, and allowed user-defined ratios of clients across bands
- ✓ ARM's spectrum load balancing feature uniformly distributed clients across channels in high-density environments served by multiple access points

This document is organized as follows. This section introduces the test project. Section 2 describes the test methodology and test bed. Section 3 describes features validation testing. Section 4 describes

[1] An 80-user office is more than four times larger than the average U.S. workplace, according to a survey by the U.S. Census bureau. That survey found 115.0 million employees in 5.9 million companies, or about 19.6 employees per firm. If anything, average office size is smaller, since the survey tabulated *firms* and not *locations.*

enterprise testing on the 80-client over-the-air test bed. Section 5 summarizes test results. Appendices at the end of this document describe the test bed infrastructure.

## 2: Test Methodology

**The primary objective of this project was to validate the effectiveness of Aruba's ARM feature set in a high-density client environment.** To accomplish that goal, Aruba constructed a large over-the-air test bed comprising an Aruba 6000 controller; four dual-band Aruba AP-105 access points; and 80 client PCs representing a mix of PC vendors, operating system versions, and WLAN chip sets.

A cardinal rule in benchmarking is to isolate one variable at a time. Because ARM encompasses multiple features – including air time fairness, ARM-aware noise reduction, band balancing, band steering, and spectrum load balancing – test engineers divided this project into two parts. *Features validation testing* examined each ARM feature individually, comparing its effectiveness versus one or more test cases without that feature enabled.

With each feature characterized on its own, engineers then moved on to *enterprise testing,* a massive undertaking involving 80 densely packed clients simultaneously handling heavy loads over the air. To add to the challenges in enterprise testing, engineers required the Aruba system to enforce a given service-level agreement (SLA) for all clients. Engineers again compared results from test cases with and without ARM features enabled.

### The Test Bed

Designing an over-the-air test bed that produces repeatable results can be a challenging proposition. Although there is no one-size-fits-all definition of "real-world" networking, especially for RF environments, Aruba achieved a meaningful representation of enterprise network conditions.

Aruba leased a 16,000-square-foot office building for this project, complete with cubicles, offices, conference rooms, carpeting, tiled ceilings, and a mixture of steel and glass walls – in short, most of the common conditions network architects will need to take into account when deploying 802.11n in the enterprise.

Figure 1 shows a floor plan of the test site, which can comfortably accommodate around 60 to 80 employees. This test bed models a scenario in which all employees have notebook PCs, and some also may have dual- or single-mode voice over WLAN (VoWLAN) phones.


**Figure 1: The Aruba Physical Test Bed**

For client PCs, Aruba deliberately deployed a mix of computer vendors, operating system versions, and WLAN chip sets, just as one might expect to find in enterprise networks. Appendix A lists the various client types and versions deployed on the test bed.

To model the challenges faced in high-density RF environments, Aruba's engineers placed PCs relatively close to one another. Most cubicles held at least two PCs and some held three. This is an increasingly common occurrence with employees using one PC and one VoWLAN device, or multiple PCs.

For test traffic, Aruba modeled a downstream pattern, where traffic moves mainly from wired Ethernet in the core toward WLANs at the edge of the network. Heavy loads, such as those used here, are highly stressful on the controller, on the access points, and on the RF spectrum.

To generate enough load to fully stress Aruba's ARM features, Aruba and Network Test chose the VeriWave traffic analysis system. This system has three components: The WaveTest 90 chassis for gigabit Ethernet and 802.11b/g/a/n-capable test interfaces (Aruba used the former on this project); WaveAgent software agents residing on the various PCs on the test bed; and WaveInsite, an application that generates test traffic between the WaveTest 90 hardware and WaveAgent software, and analyzes results after each test. As a purpose-built test instrument, the VeriWave system is capable of generating traffic up to and beyond theoretical line rate in a precise and repeatable way.

Figure 2 illustrates the logical test bed, including the Aruba 6000 series controller; Aruba AP-105 access points; and VeriWave test tools; and test bed infrastructure. Aruba engineers populated the Aruba controller with two M3 modules – one apiece for the access points and Aruba Spectrum Analyzer.

The access points used in this project were four Aruba AP-105s, with two additional Aruba AP-105s deployed as air monitors.

Appendix B lists the software versions used for the Aruba system under test and VeriWave test equipment.

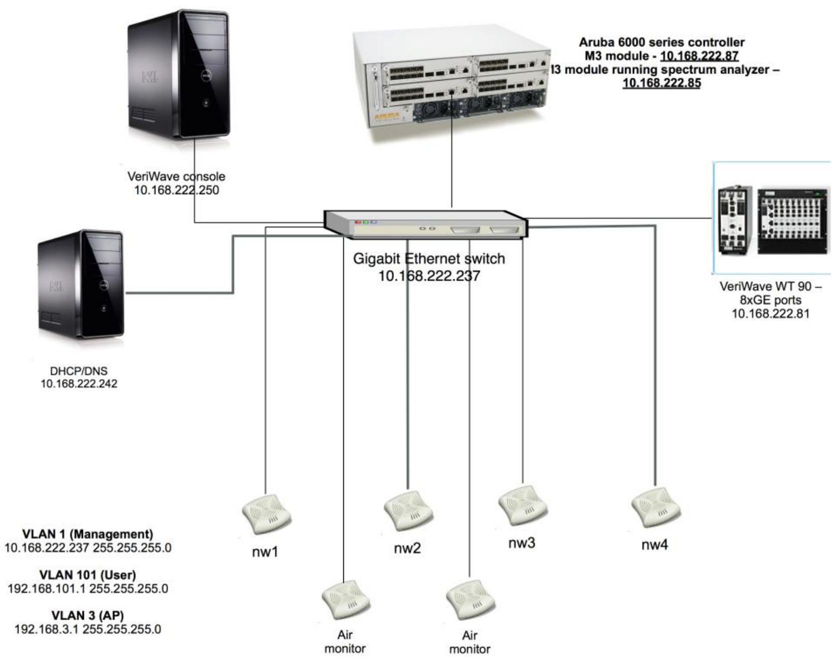


**Figure 2: The Aruba Logical Test Bed**

## Initial Site Survey

Although repeatability is a bedrock requirement in network device benchmarking, it can be an elusive goal when it comes to over-the-air WLAN testing. Interference from outside noise sources is always a major concern with over-the-air testing. To verify the test site was "clean" from an RF perspective, test engineers began this project with a site survey to determine what interference sources, if any, might affect test results.

Engineers used two tools to characterize the RF environment: A pre-release version of the Aruba Spectrum Analyzer, which runs on an M3 module in the Aruba 6000 controller; and the WildPackets OmniPeek Network Analyzer, which captures and decodes 802.11 frames.

Frame captures taken in two locations with OmniPeek revealed little or no interference from outside sources. In the first location, near the control room where engineers ran tests, OmniPeek captured no frames when the Aruba access points were powered off. In the second location, at the far end of the test site, OmniPeek did capture two beacon frames from an outside source in a 60-second period. OmniPeek reported a signal level for both frames at -97 dBm, below the noise floor and thus not a significant interference source. Two beacon frames in 60 seconds is very little traffic; by default, access points typically send one beacon every 100 milliseconds.

The Aruba Spectrum Analyzer also confirmed that the air was quiet during testing. Both in the initial site survey and again via spot-checking during the test cycle, the Spectrum Analyzer showed no significant channel utilization when the Aruba access points and client PCs were powered off.

For example, Figure 3 shows the Aruba Spectrum Analyzer's view of the 2.4GHz band. As the graphics in the Spectrum Analyzer show, all channels within that band are virtually silent. For example, the top-right hand chart shows power levels of around -95 dBm on all channels, below the noise floor.

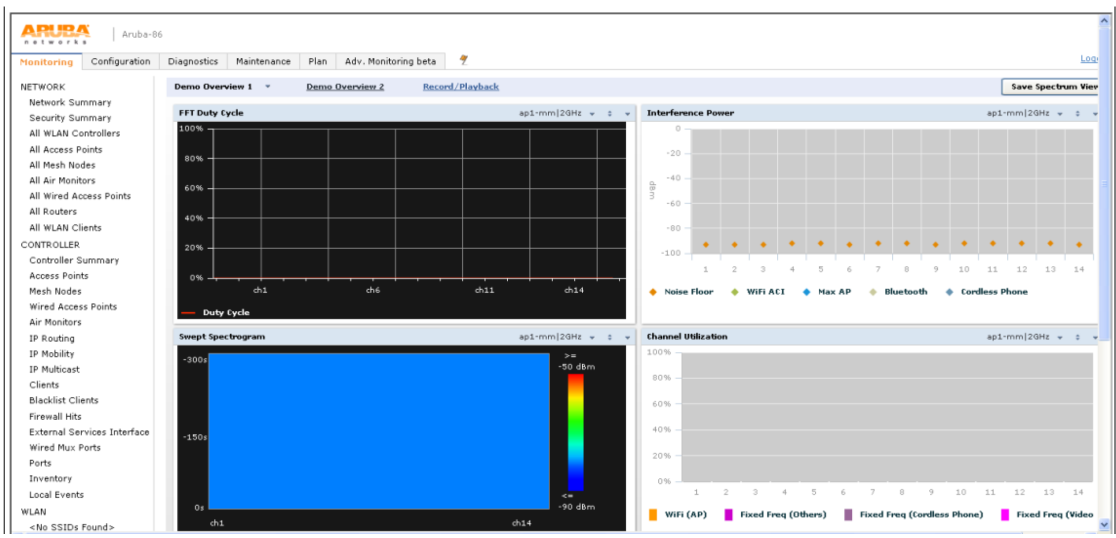


Figure 3: Aruba Spectrum Analyzer Site Survey

This site survey validated that the test bed was clean from an RF perspective. Based on readings from both the Aruba Spectrum Analyzer and OmniPeek, engineers were confident came from, and only from, the traffic offered during benchmarking.

# 3: Features Validation

ARM comprises multiple RF management mechanisms aimed at boosting application performance. These mechanisms include air time fairness; noise-aware ARM; band steering; and spectrum load balancing.

The enterprise performance tests described later in this documents show all these mechanisms working together to optimize RF performance. However, as with any test involving multiple variables, it makes sense to first consider and validate each mechanism on its own.

As noted in the executive summary, many problems with RF management exist in high-density client settings. Figure 4 summarizes these problems, the solutions offered by ARM, and the validation status of each solution as described in the next few sections.

| Problem | Aruba ARM solution | Validated? |
|---|---|---|
| Legacy clients take up too much air time | Air time fairness | ✓ |
| Channels become saturated | Band balancing, spectrum load balancing | ✓ |
| Noise on one channel spills over onto other channels | Noise-aware ARM | ✓ |
| One set of identical clients unfairly soaks up spectrum | Air time fairness | ✓ |
| Unfair client distribution across bands and channels | Band balancing, spectrum load balancing | ✓ |
| Clients associate to wrong APs | Spectrum load balancing | ✓ |

**Figure 4: Issues Addressed By Aruba ARM Features**

## Air Time Fairness

Ensuring fairness on shared-access 802.11 networks can be difficult. Horror stories abound: Distant clients take up excessive air time via retransmissions; lower-speed legacy clients monopolize air time, starving application performance for faster 802.11n clients; and even similar clients can degrade one another's performance if one set of PCs associates at a lower rate than the other.

*Air time fairness,* a key part of Aruba's ARM features set, gives network managers the final say over how clients gain access to the WLAN medium. **Air time fairness grants access to clients using a token-based system, with preferred clients getting more tokens and thus more time to transmit data.** The token concept also is useful in network management; by viewing the Aruba controller's command-line interface (CLI), administrators can see at a glance which clients are the top talkers on the network.

Air time fairness can be configured in fair and preferred access modes. With *fair access,* the system grants an equal number of tokens, and thus equal access, to each client. With *preferred access,* the system grants more tokens to 802.11n clients, ensuring they are not crowded out by slower 802.11a/b/g clients that require more air time.

Network Test validated the correct operation of airtime fairness in three scenarios: A “near/far” test and two tests involving different combinations of 802.11n and legacy clients. In all cases, engineers compared results with air time fairness enabled and disabled.

## Air Time Fairness: Near/Far Testing

In the near/far test, engineers compared performance for two clients associated to the same AP – one close to the AP, while the other was at the opposite end of the building used for testing (see Figure 5). Despite the great distance between clients, UDP goodput (forwarding rate, minus retransmitted frames) to both clients were around 15-17 Mbit/s in the default case with air time fairness disabled.


**Figure 5: Near/Far Fairness Test Bed**

In this default test case without fairness, the far client associated to the AP at a lower rate and suffered many more retransmissions than the near client. The Aruba 6000 controller indicated the second (far) client suffered from a low association rate (30 Mbit/s, vs. 300 Mbit/s for the near client) and dropped far more frames. The far client’s weak RF characteristics required more air time – and this in turn caused the *near* client’s application performance to suffer, even though its RF characteristics were excellent.

**With fair access enabled, UDP goodput nearly tripled for the near client,** with relatively little degradation for the far client (see Figure 6). The differences are stark: Fair access improves the near client's time on the air by 136% and transfer rates by 178%.

Thus, **air time fairness significantly improved performance for a nearby client with minimal degradation for a far client.** The offered load for both clients was 50 Mbit/s; thus, air time fairness improved the near client's performance so that it received data near the highest possible rate.

| | | Default access | | Fair access | | | |
|---|---|---|---|---|---|---|---|
| | **PHY rate (Mbit/s)** | **Tx time (ms)** | **Goodput (Mbit/s)** | **Tx time (ms)** | **Tx time improvement** | **Goodput (Mbit/s)** | **Goodput improvement** |
| **Near client** | 300 | 2,046 | 17 | 4,820 | **136%** | 47 | **178%** |
| **Far client** | 30 | 12,888 | 15 | 11,262 | NA | 13 | NA |

Figure 6: Near/Far Improvements With Air Time Fairness

## Air Time Fairness: Legacy Coexistence

**Air time fairness also can help mediate access between speedy 802.11n and slower legacy clients.** Test engineers used two scenarios to assess the effectiveness of this feature. The first involved an AP's 5-GHz radio and a mixture of 802.11n and 802.11a clients, while the second involved an AP's 2.4-GHz radio and a combination of 802.11n, 802.11g and 802.11b clients. This latter case is especially meaningful for enterprises that use VoWLAN; many older handsets support only 802.11b or 802.11g modes, and can hinder performance of faster 802.11n clients.

For both 2.4- and 5-GHz scenarios, engineers ran separate tests with air time fairness disabled, and again enabled in fair and then (in the 2.4-GHz tests) preferred modes. In fair mode, all clients gain equal access to the medium; with preferred mode, the Aruba ARM system grants more air time, and thus more opportunities to transmit, to high-speed clients. Engineers used three metrics to compare performance: air time; UDP goodput; and channel utilization. For all three metrics in both 2.4-and 5-GHz test cases, enabling fair access led to dramatic performance improvements.

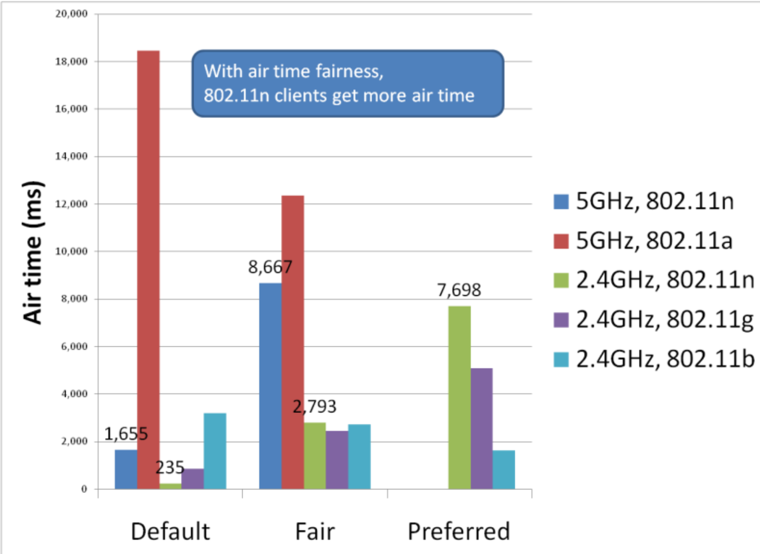


Figure 7: Air Time Fairness Client Comparison

Figure 7 compares air time access, as reported by the Aruba 6000 controller, in default, fair access, and preferred modes. **Note the percentage improvements for 802.11n clients gaining air time; these are up to 1089% in fair access mode, and up to 3176% in preferred access mode.**

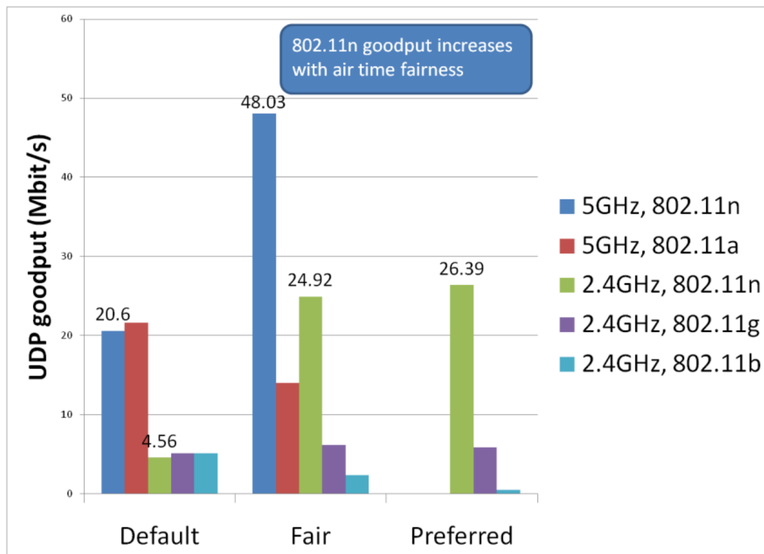


Figure 8: UDP Goodput With Air Time Fairness

Figure 8 compares UDP goodput in the various fairness modes. Here again, **performance picks up for 802.11n clients when air time fairness is enabled, with goodput improvements of up to 479%** (in the preferred mode test case in the 2.4-GHz band).

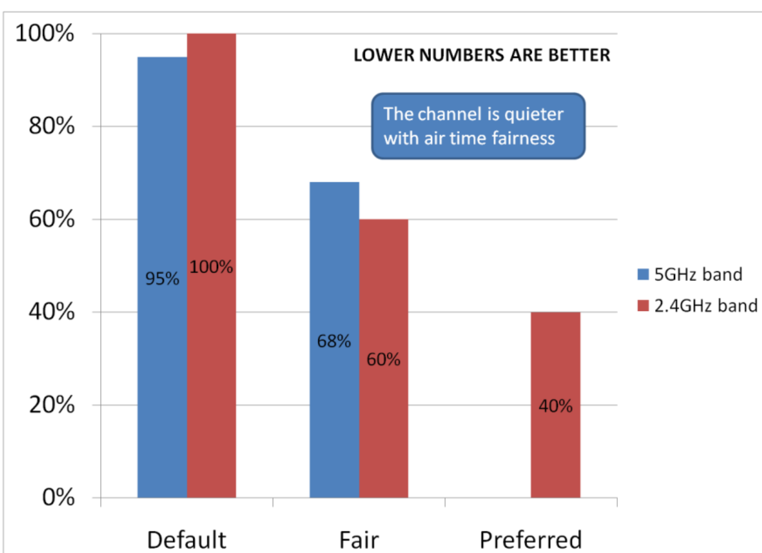


Figure 9: Channel Utilization Comparison

Figure 9 compares channel utilization, which decreased sharply with air time fairness enabled. In the default access mode, legacy clients saturated the channel. Enabling fair access freed up half or more of available spectrum. Thus, **the RF medium was less than half as busy in the preferred access test case.**

## Noise-Aware ARM

As anyone who's spent five minutes with a spectrum analyzer can attest, RF interference is an ongoing concern when it comes to management of 802.11 networks. Noise sources include not just WLAN networks but also Bluetooth devices, microwave ovens, and cordless phones, both in the 2.4- and 5-GHz bands. The frequency bands used by WLANs are crowded; the question for network managers is what the WLAN infrastructure does to deal with outside noise.

**Aruba's *noise-aware ARM* feature mitigates the effects of outside interference by recognizing noise and steering clients onto other channels.** This adaptive feature helps protect application performance by heading off connectivity problems before they occur.

To validate the effectiveness of noise-aware ARM, test engineers used a Terk LF30S video bridge, a device that transmits video signals in the 2.4-GHz band, as an interference source.

After associating a Windows XP client to an Aruba AP and setting up a continuous ping with a host on the wired network, engineers then observed the Aruba spectrum analyzer and Aruba 6000 controller output three times: Before and after turning on the video bridge, and once more after the controller's `noise-wait-time` interval had passed.

In the first observation, the spectrum analyzer showed an active AP on Channel 6 and relatively low signal on other channels (see Figure 10).


Figure 10: Channel Utilization Before Outside Signal Generation

It was a very different picture after engineers powered up the video bridge (see Figure 11). Here, engineers observed near saturation of nearby channels, resulting in total packet loss for the client sending ping messages.


Figure 11: Channel Utilization During Outside Signal Generation

In testing, engineers used the Aruba controller's `noise-wait-time` default interval of 120 seconds, meaning that the controller would move the AP to a different channel if it observed outside noise of greater than -75 dBm for that interval.

Indeed, that is exactly what happened. After slightly longer than two minutes of interference from the video bridge, **the controller moved the associated client to the less busy channel** (see Figure 12). Here, because the RF environment was considerably cleaner on Channel 1, **the client was able to resume sending and receiving** ping requests and responses.


Figure 12: Channel Utilization With Noise-Aware ARM Enabled

In staging the noise-aware ARM test, Aruba test engineers timed the channel-change interval, both using the default 120-second value and a 15-second interval. Network Test did not observe these tests, but they are consistent with cutover times that Network Test did observe during on-site testing. Figure 13 summarizes channel change times as observed by monitoring Aruba 6000 controller output. Results were very consistent across multiple test runs, both in Aruba's staging and in testing observed by Network Test.

| | 15-second noise-wait-time interval | 120-second noise-wait-time interval (default) |
|---|---|---|
| **Run 1** | 19s | 132s |
| **Run 2** | 19s | 133s |
| **Run 3** | 21s | 132s |

**Figure 13: Noise-Aware ARM Mitigation Times**

## Band Steering

Since 802.11 WLANs use a shared-access medium, channel utilization is always a concern. As channels become more heavily saturated, application performance suffers. This is especially true in the 2.4-GHz band, where only three truly usable channels exist and contention from legacy and non-802.11 sources can be fierce. What's really needed is a means for moving clients away from congestion.

The *band steering* feature in ARM provides just such a means. **Band steering continually monitors channel utilization and directs dual-band clients toward the less congested 5-GHz band.** As a result, these high-speed clients won't have to contend for bandwidth with legacy clients that use more time slots in the 2.4-GHz band. For all clients, the result is less interference and more available channels.

Band steering has multiple configuration modes. In *preferred* mode, band steering encourages dual-band clients to use the less congested 5-GHz band if available. In *band balancing* mode, the Aruba system allocates clients across the 2.4- and 5-GHz radios on the same access point according to a preconfigured ratio. In *force* mode, band steering always assigns dual-band clients onto 5-GHz channels.

Network Test validated the effectiveness of band steering with four tests: with the feature disabled and then enabled in preferred, band balancing, and force modes. All four tests involved 20 clients, each with dual-band 802.11n chip sets, and each associated to a single AP with both 2.4- and 5-GHz radios enabled.

As Figure 14 illustrates, all clients were closely packed around the same access point. In this setting, performance in the 2.4-GHz band can be especially problematic, with clients contending for a single 20-MHz channel and interfering with one another. (While this example uses a single access point, the problem actually grows more severe as the network scales up with multiple access points in use. In that case, clients may contend for bandwidth across multiple instances of the same channel provisioned on multiple access points.)


**Figure 14: The Band Steering Test Bed**

In the test case with band steering disabled, clients associated to each radio appeared in a seemingly random pattern. In repeated trials, engineers observed anywhere between two and 10 clients associating to channels in the 2.4-GHz band, with others associating to channels on the 5-GHz band.

**Results were much more predictable with the controller configured in band steering's preferred mode.** Here, repeated trials yielded the same result: Three clients associated with the 2.4-GHz radio, and the remaining 17 clients associated with the 5-GHz radio.

To assess band balancing, engineers used the Aruba controller's default ratio of 1:4 between 2.4- and 5-GHz band associations. **The expected result with band balancing was to have four times as many clients associate with a 5-GHz radio – and that is exactly what happened,** as reported by the Aruba controller. **The "force" mode also result produced the expected result,** with all 20 clients associating with the 5-GHz radio and no clients associating in the 2.4-GHz band.

Figure 15 summarizes client association counts using band steering's various configuration modes.

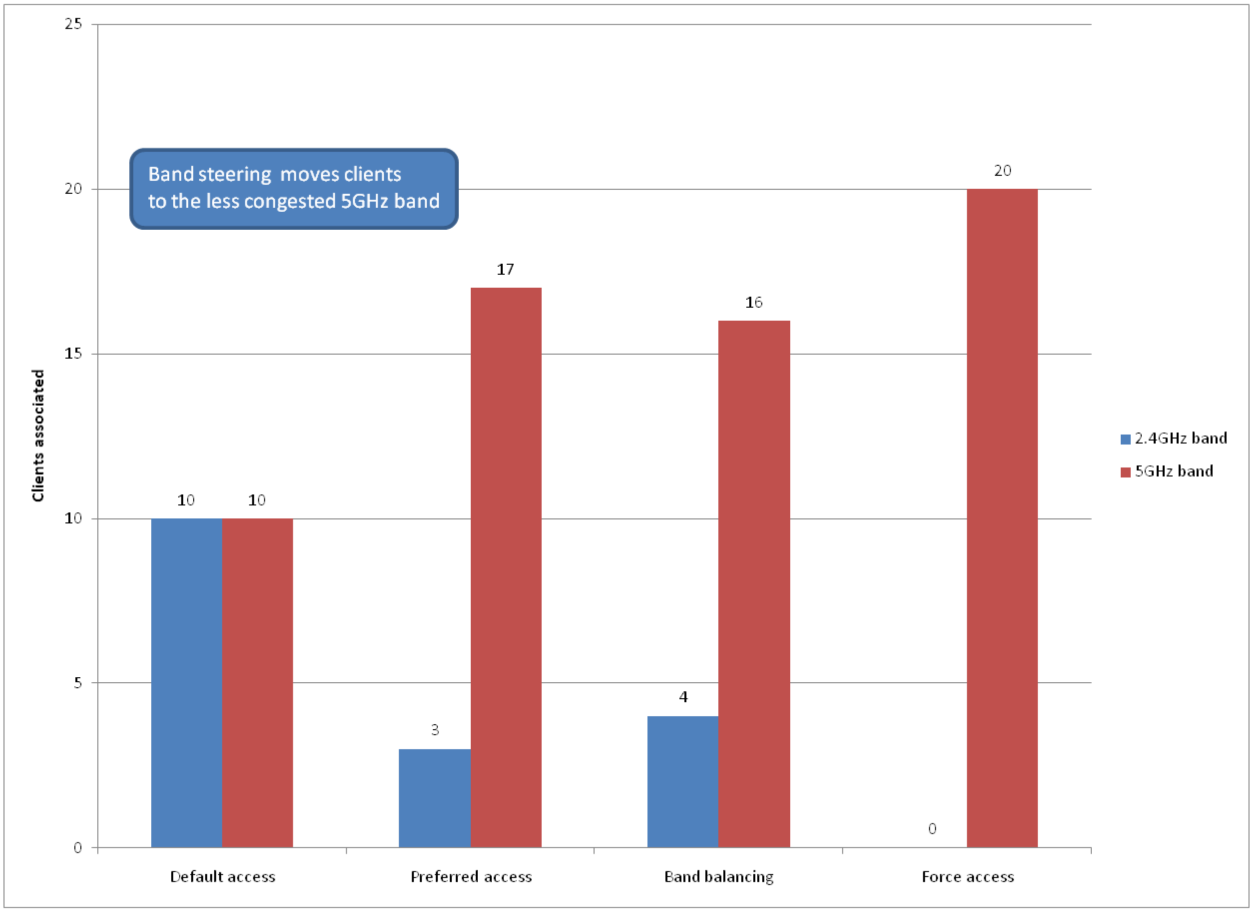


**Figure 15: Band Steering Client Distribution**

## Spectrum Load Balancing

While band steering can be highly useful in distributing clients equitably across *bands* on a single access point, there is still the problem of clients overloading *channels,* especially when enterprise networks deploy multiple access points in close proximity to handle large numbers of clients.

That's where **Aruba's ARM *spectrum load balancing*** comes in: It **takes a holistic view of the network, dynamically balancing clients across channels on multiple access points.**

Spectrum load balancing is particularly useful in the 2.4-GHz band. Even if no legacy clients exist (an unlikely assumption in many enterprises), high-speed clients still have only three usable channels to work with. This is an acute problem in high-density settings, where channel bandwidth remains a scarce commodity regardless of the number of APs deployed. Dynamically balancing clients across channels helps make the best use of available spectrum.

Test engineers validated the effectiveness of spectrum load balancing by comparing client counts on each channel with and without this feature enabled. In both cases, engineers began by bringing up four access points, each using only their 2.4-GHz radios. With four access points and only three usable channels available, spectrum load balancing would have to distribute clients uniformly across the same channel on multiple access points.

After waiting approximately five minutes for ARM coverage to settle, engineers then powered up 15 notebook PCs and used the Aruba 6000 controller's `show ap active` command to note the number of 802.11n clients associated to each channel.

In the default case without spectrum load balancing, association patterns across APs and channels 1, 6, and 11 used a random distribution. A second run of the same test produced a different outcome, but again there was no discernable pattern of client distribution across APs and channels.

After enabling spectrum load balancing and running the same test twice more, client association patterns were much more uniform across channels (see Figure 16). While results varied slightly between runs with spectrum load balancing enabled, variation among client counts (expressed here as standard deviation) was far lower in both cases. By distributing clients more equitably across channels, **spectrum load balancing reduced bandwidth contention for all clients.**

| | Clients on Channel 6/ AP1 | Clients on Channel 1/ AP2 | Clients on Channel 11/ AP3 | Clients on Channel 1/ AP4 | Standard deviation |
|---|---|---|---|---|---|
| **SLB disabled, run 1** | 13 | 0 | 0 | 2 | 6.24 |
| **SLB disabled, run 2** | 9 | 0 | 4 | 2 | 3.86 |
| **SLB enabled, run 3** | 5 | 2 | 4 | 4 | 1.26 |
| **SLB enabled, run 4** | 5 | 1 | 4 | 5 | 1.89 |

**Figure 16: Spectrum Load Balancing and Client Distribution**

## 4: Enterprise Testing: Meeting SLA Thresholds

While the foregoing tests have verified each ARM feature on its own, the ultimate validation is enable all features concurrently, and determine what benefits they offer for the application performance of many clients in a high-density environment.

In this most challenging of all over-the-air tests, engineers brought up four dual-band Aruba AP-105 access points serving 80 clients in a dense setting (see Figure 17). The squares show which cubicles were in use during testing; in fact, each cubicle housed at least two and in some cases three notebook PCs. This is an increasingly common occurrence, with users wirelessly associating multiple PCs, or PCs and VoWLAN-enabled devices, to the enterprise network.


**Figure 17: The Aruba Enterprise Test Bed**

Into this already challenging environment, engineers introduced two more elements to push the limits of application performance. First, engineers used only downstream UDP traffic in application testing. Because UDP is stateless, it involves high and steady packet rates. There is no “breathing room” introduced while packets wait for acknowledgements, as with stateful TCP. Thus, UDP packet and bit rates are more stressful on the controller and access points.

Second, engineers checked for service-level agreement (SLA) enforcement using the VeriWave equipment. To pass a test, every single flow generated by VeriWave’s WaveInsite application had to meet an SLA of delivering an achieved load of at least 80 percent of the offered load (offered load is the rate at which traffic goes into the test bed, while achieved load is the rate at which clients receive it).

To get a sense of the effectiveness of ARM features, engineers ran this large-scale test both with and without ARM enabled. In the test case with no RF management, engineers statically configured channels and power levels for each access point.

Although both test cases involved the same traffic load, engineers measured each result four ways: in terms of aggregate goodput, SLA enforcement, client distribution, and channel utilization. Each metric says something different about ARM’s ability to enhance application performance.

In terms of system goodput – the aggregate rate at which all clients receive UDP traffic – rates were around 50 percent higher with ARM enabled than without RF management. Indeed, with ARM enabled the Aruba system delivered traffic at a total rate of close to 600 Mbit/s.

Figure 18 summarizes UDP goodput results across the various test cases.

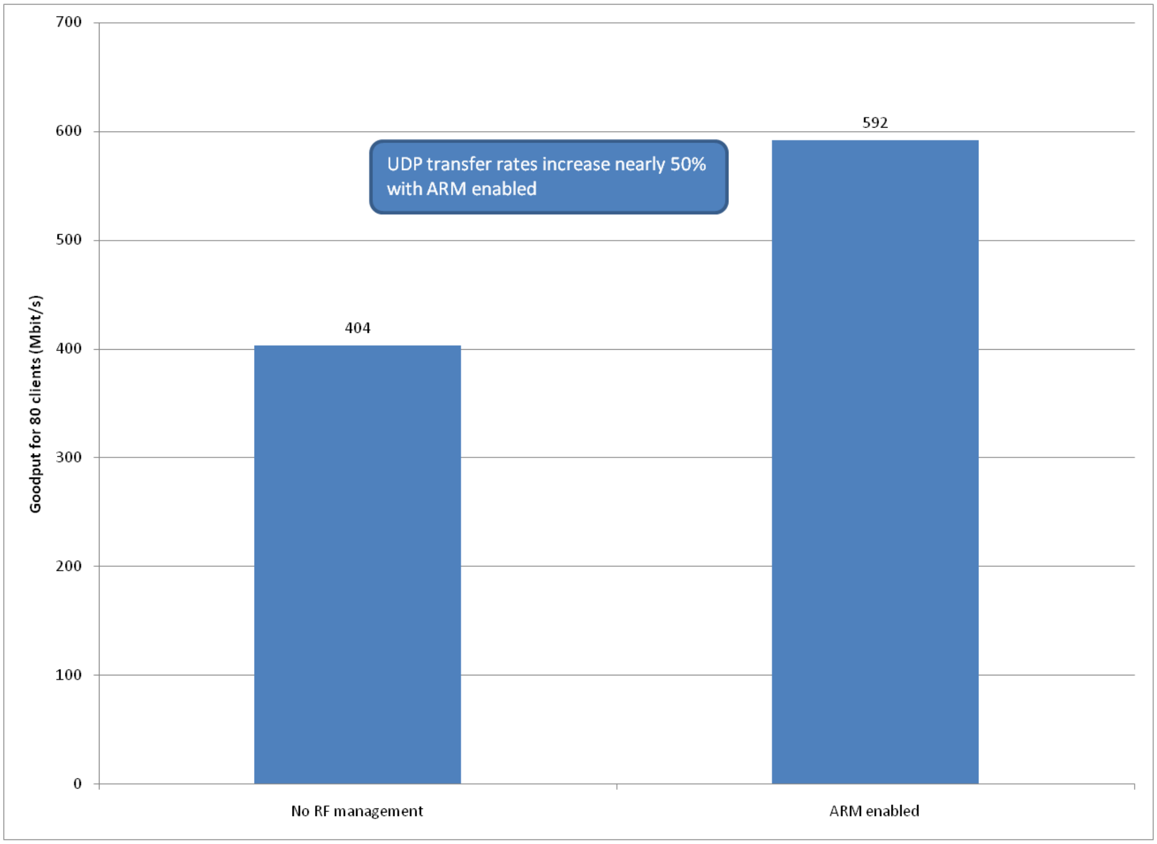


**Figure 18: Aggregate Goodput for Four APs, 80 Clients**

Significantly, the Aruba controller and APs met SLA targets for all 80 clients with ARM enabled. With no RF management features enabled, in contrast, only 23 percent of clients met the SLA objective of an achieved load rate of at least 80 percent of the offered load.

The results again suggest that ARM's combination of RF management features ensures each high-speed client makes efficient use of air time, and this in turn translates into improved application performance.

Figure 19 summarizes results from the SLA enforcement tests.

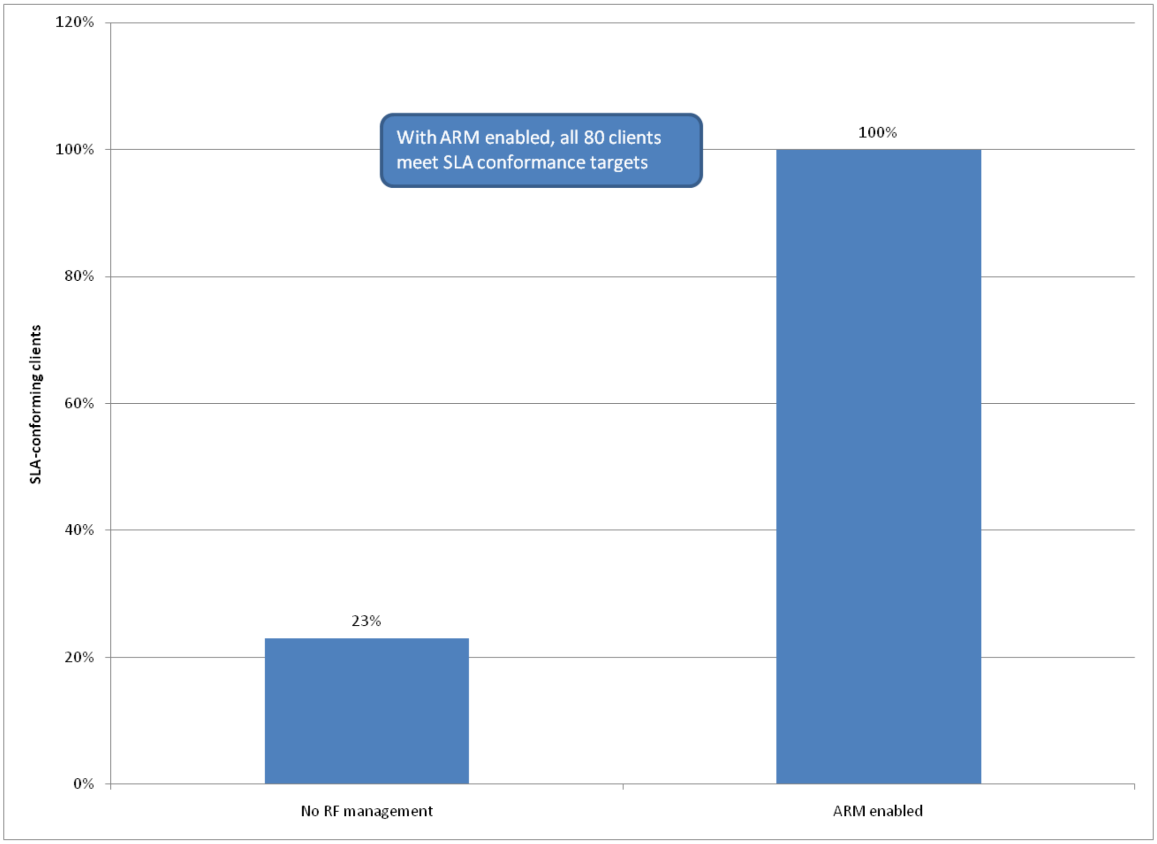


**Figure 19: RF Management and SLA Enforcement**

As noted, efficient distribution of clients across APs and channels is a critical part of ensuring optimal application performance. Engineers monitored client counts in every test case; in every iteration, the client distributions were far more uniform in test cases with ARM enabled.

Indeed, without ARM, clients associated to seemingly random APs in the dense test environment. This led to oversubscription of some APs and channels, with predictable negative consequences for application performance. For example, Channel 1 on the APs labeled “nw1” and “nw3” in the 2.4GHz band was loaded far more heavily than other 2.4GHz channels on other APs, causing associated clients to experience low goodput.

Figure 20 summarizes client distributions across the various test cases.

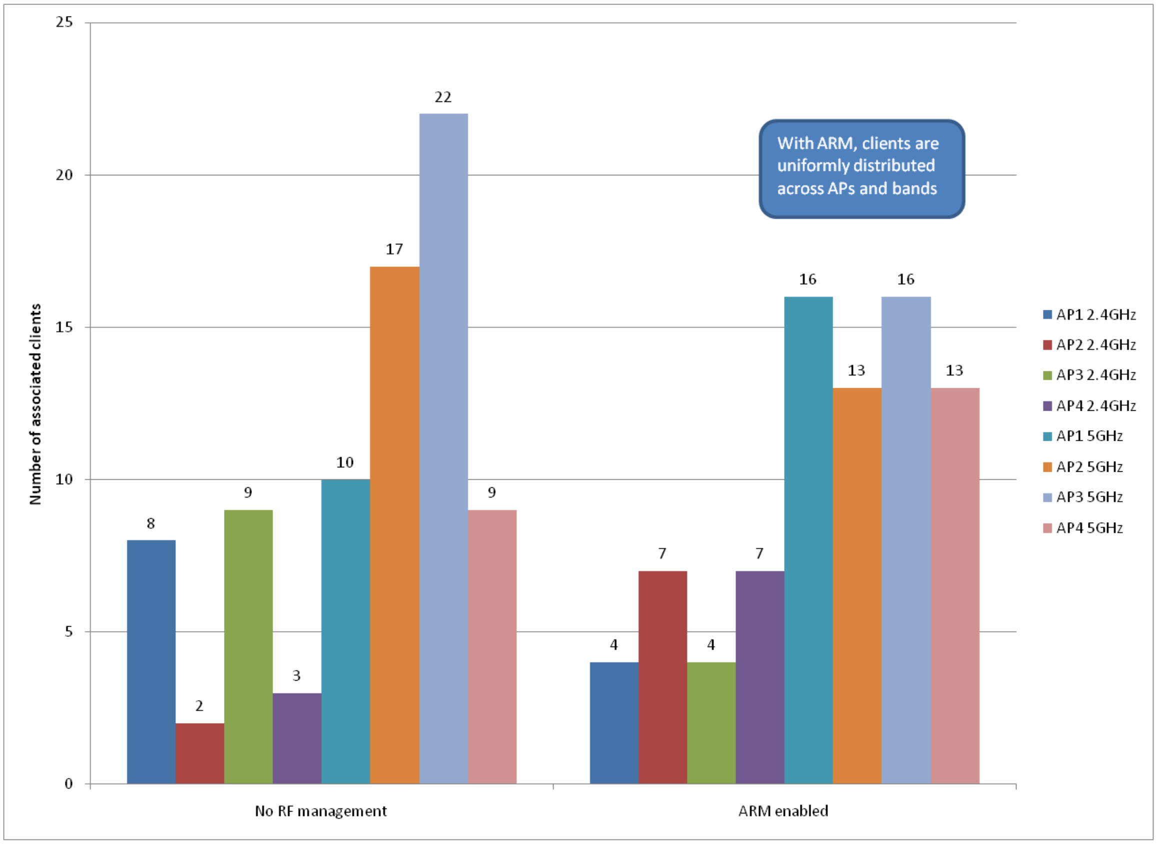


**Figure 20: Client Distribution With and Without ARM**

Channel utilization was the ultimate check on ARM's RF management efficiency. With so many clients contending for scarce bandwidth in the dense test environment, it is understandable to expect heavy channel utilization. The question for ARM was what it would do to mitigate the heavy RF load.

Using statistics reported from the Aruba 6000 controller and the Aruba spectrum analyzer, engineers monitored channel utilization loads with and without ARM. The medium was notably less busy in tests with ARM enabled, with overall channel utilization of 52-62 percent, compared with utilization levels of up to 80-90 percent in tests without these features enabled.

With ARM's lower channel utilization, existing clients can use the additional bandwidth for higher application performance; or more clients can associate to the network; or network managers can use some combination of the two. However it's used, available channel bandwidth almost always equates to improved application performance for clients.

Figure 21 compares channel utilization with and without ARM.

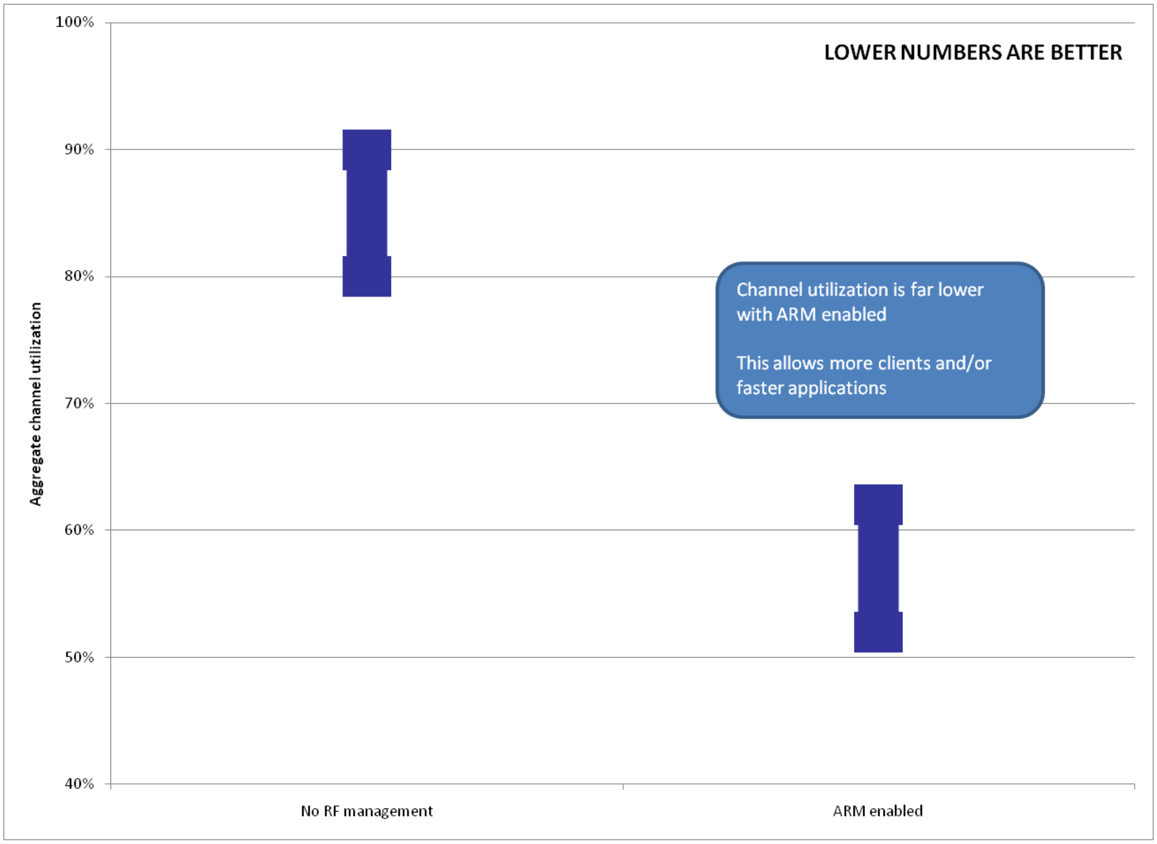


**Figure 21: Channel Utilization With and Without ARM**

## Over-The-Air Testing: A Cautionary Tale

As noted in the previous section, dynamic RF management facilities such as ARM *almost* always improve application performance for clients – but as engineers discovered on this project, there are exceptions having nothing to do with the RF environment. These experiences may provide a cautionary tale for enterprises looking to conduct their own over-the-air testing.

During initial goodput testing, some clients exhibited significantly lower goodput than their neighbors, even though their RF characteristics were about the same. Through trial and error, engineers found that the "slower" clients always shared a common make and model of WLAN chip set.

By comparing packet counts on the Aruba controller with packet captures taken over the air and on the slower clients, it became clear that the Aruba system actually was delivering all traffic to each client as expected – but that the clients' WLAN driver was dropping frames before passing traffic up the stack to the VeriWave WaveAgent test software. As a result, the WaveAgent client software reported low performance numbers even though the Aruba controller and APs performed as expected.

Although a driver upgrade and some buffer tuning in the VeriWave client addressed this issue, it is yet another reminder of the many extraneous factors that can affect measurements when it comes to over-the-air testing. Systems testing is a complex undertaking involving many components. Without characterization of each component, it's all too easy to produce results that say more about the components than the system under test.

# 5: Conclusion

RF spectrum is a scarce resource that can be difficult to manage – and that's before adding in factors such as mixtures of 802.11n and legacy clients and high-density environments.

As these test results have shown, Aruba's ARM feature set tames the RF environment. Features such as air time fairness give network managers control over which clients gain access to the wireless medium, and for how long. Noise-aware ARM deals with interference from other sources, which is a particular concern in the constrained 2.4-GHz band. Band steering moves high-speed clients to the less congested 5-GHz band. And spectrum load balancing works holistically to balance clients across channels running on multiple access points.

Taken together, the ARM features work to provide much improved application performance, even in dense client environments. By several measures, ARM improves performance over the air: Goodput and SLA conformance are far higher with ARM than without; client distribution is more uniform; and channel utilization also is far lower. The ARM features improve performance, and in the process make RF management a far less difficult task, even in high-density client environments.

# Appendix A: Client PC Descriptions

This appendix lists specifications for the 80 PCs used on the test bed. Instead of listing specifications for all 80 machines individually, the following descriptions are broken down to show PC counts by vendor and model; WLAN chip set maker and model; and operating system version.

## By PC Make and Model

| Vendor/model | Count |
|---|---|
| Dell Inspiron 1525 | 1 |
| Dell Inspiron 1545 | 3 |
| Dell Latitude D620 | 50 |
| Dell Latitude D630 | 1 |
| Dell Latitude D830 | 11 |
| Dell Latitude E5400 | 1 |
| Dell Vostro 1510 | 6 |
| HP Mini | 1 |
| HP Pavilion Tx 1000 | 3 |
| HP Pavilion Tx 1000 | 3 |
| **TOTAL** | **80** |

## By WLAN Chip Set

| Vendor/model | Count |
|---|---|
| Atheros Dell 1515 | 5 |
| Broadcom 321 | 1 |
| Broadcom 4321 | 2 |
| Broadcom 4322 | 3 |
| Intel 4965 | 68 |
| Intel 5300 | 1 |
| **TOTAL** | **80** |

## By Operating System Version

| OS version | Count |
|---|---|
| Windows 7 Home Premium | 4 |
| Windows 7 Enterprise | 2 |
| Windows Vista Business | 10 |
| Windows Vista Home Basic | 10 |
| Windows Vista Home Premium | 3 |
| Windows XP Home | 1 |
| Windows XP Professional | 50 |
| **TOTAL** | **80** |

# Appendix B: Test Bed Infrastructure Software Versions

This appendix describes the software versions used on test bed infrastructure, including the Aruba system under test and the VeriWave test equipment.

## Aruba System Under Test

| **Component** | **Version** |
|---|---|
| Controller | Aruba 6000, 2 x M3 modules |
| Access point | Aruba AP-105 |
| Software release | AOS 3.4.3.0 build 24282 |
| Spectrum analysis module | AOS 6.0 build 24224 |

## VeriWave Test Equipment

| **Component** | **Version** |
|---|---|
| WaveTest WT90 chassis firmware | 3.92, 2010.05.18.14 |
| WaveTest software | 3.92, 2010.05.18.15 |
| WaveInsite software | 2.0 |
| WaveAgent client software | 1.1.0,2010.06.09.05 |

# Appendix C: Disclaimer

Network Test Inc. has made every attempt to ensure that all test procedures were conducted with the utmost precision and accuracy, but acknowledges that errors do occur. Network Test Inc. shall not be held liable for damages which may result for the use of information contained in this document.

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